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Investigating teachers' practices for non-specialist students

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Our study concerns teaching practices in the case of non-specialist first-year university students. Referring to the Anthropological Theory of the Didactic and drawing on background literature and on our previous work, we identified five didactic types of tasks, which may especially concern teachers of non-specialist students. We designed a questionnaire in which we asked teachers if they perform these types of tasks, how, and what are the reasons for their choices. When teachers declare they never address a type of tasks we investigate the reasons they present; otherwise, we investigate their declared didactic praxeologies. An analysis of the answers collected shows that, while the types of tasks are performed by a majority of teachers, a significant number of them do not give reasons for their choices.

Keywords: Anthropological theory of the didactic, Teachers' and students' practices at university level, Teaching and learning of mathematics in other disciplines.

INTRODUCTION

The study presented here concerns university teachers' practices, when they teach mathematics to first-year science students, not specialised in mathematics. Difficulties of non-specialist students with mathematics have been internationally observed. Taking these difficulties into account, some studies propose specific interventions: mathematics courses oriented towards applications, project-based teaching, for example (e.g. Härterich et al. 2012). These interventions seem to have a positive impact on non-specialist students' learning, and on their interest in mathematics. On the other hand, the ordinary practices of teachers for these students have rarely been the subject of research, even though studies of teaching practices have expanded in recent years (Biza et al., 2016). In Gueudet et al. (2022), we presented a first exploratory study: using the Anthropological Theory of the Didactic (ATD, Chevallard, 1999) we investigated the declared teaching practices of three teachers, and tried to identify didactic praxeologies specific to non-specialists students. Building on this first step, we designed a questionnaire for university teachers and submitted it to teachers involved in the teaching of mathematics to non-specialists in France and in Argentina. These two countries were chosen for a comparison that will be part of our further work, but will not be considered here. In this paper we present this questionnaire and analyse the answers collected.

THEORETICAL FRAMEWORK

The Anthropological Theory of the Didactic (ATD, Chevallard, 1999) proposes that all human activity regularly developed can be described using an essential and founding model: that of *praxeology*. This includes two key and inseparable elements: praxis and

logos. The first refers to the *know-how part*, that is, the types of problems or tasks that are studied and the techniques that are used to solve them. The “logos” is identified with the *knowledge part*. It includes the technological rationale that gives meaning to the proposed problems, and allows the techniques to be interpreted. The theory justifies the technological descriptions and foundations. In this way, any praxeology consists of four elements: *tasks, techniques, technologies and theories*.

In the case of mathematical activity, Chevallard (1999) distinguishes two types of praxeologies: *mathematical organisations* (MO), which respond to “What mathematics to study”, and *didactic organisations* (DO) which respond to “How this study is carried out”, that is, ways to carry out the study of the MO or ways to achieve the teaching objectives of this MO.

In the case of didactic organisations, the components are called *didactic tasks, didactic techniques, didactic technologies, and didactic theories*. Didactic tasks represent a relatively precise object (Chevallard, 1999). For example, “teaching to model an economic system” and how to do, for example, “proposing the resolution of moderately open economic problems”. In turn, this technique or way of doing, should appear as something both correct, understandable and justified.

The existence of a technique then presupposes the existence, around it, of an interpretative and justifying technique rationale and its context of applicability and validity. This rationale is called *technology* - for example, “because solving economic problems involves the construction of mathematical-economic models that describe and predict the behaviour of the system”. Technologies can also generate techniques. In turn, a technology requires an interpretation and a justification. This is the level of *theory*, rarely appearing in the case of didactic praxeologies.

When a set of tasks shares a technique, they are grouped into *types of tasks*. Like tasks, types of tasks are also relatively precise objects. This common technique is relative. This means that, in a given institution and for a given type of task, there is in general at least one technique, or a small number of institutionally recognized techniques (Chevallard, 1999).

RELATED WORKS AND CHOICE OF FIVE TYPES OF TASKS

Research about the practices of university mathematics teachers for non-specialist students is scarce. González-Martín (2021) studies in terms of didactic praxeologies the practices of two teachers in two courses for future engineers (strength of materials; electricity and magnetism). He evidences that their use of integrals is mostly implicit in these courses; this can create difficulties for students who need to make the link between their mathematics course and these other courses. In a previous study (Gueudet et al., 2022) we interviewed three university teachers who teach mathematics for non-specialists. We identified in particular three didactic types of tasks that these teachers performed for their students: “Foster students’ interest and engagement in mathematics” (T_{iem}); “Restore students’ self-confidence in mathematics” (T_{scm}); and “Teach basic mathematics” (T_{bm} , basic mathematics means here mathematics that are

taught at grade 10 or before). The literature about the difficulties met by non-specialist students confirms that these types of tasks are likely to be especially important for non-specialist students, who might not be interested in mathematics, and perhaps experienced difficulties in mathematics at secondary school (see e.g., Kürten, 2017). Investigating further the literature about non-specialist students, we identified two other didactic types of tasks that mathematics teachers could address. As evidenced for example by Hitier and González-Martín (2022) in their study about the derivative in calculus and in mechanics courses, significant differences exist between the mathematics present in a mathematics course and the mathematics present in the course for another discipline. These authors noted that textbooks and teachers who closely follow the textbook choices in their own courses offer a reduced number of tasks in the context of the other discipline; moreover, inconsistencies exist between the praxeologies linked with the derivative in mathematics and in mechanics. This suggests a need for “Link mathematics and other disciplines” (T_{lmo}) in mathematics courses for non-specialists. Moreover, non-specialist students need to work with models containing mathematics in the other disciplines they learn. Constructing or using a mathematical model is particularly difficult if they never learned it in their mathematics courses (see e.g., for physics, White Brahmia, 2023). Thus, we consider “Teach mathematical modelling” (T_{mm}) as an important didactic type of tasks for non-specialist students.

Our study was thus designed to answer the following research questions, concerning the teaching of mathematics to non-specialist students:

RQ1. Do teachers tackle these five types of didactic tasks?

RQ2. Why do some teachers never perform a type of tasks?

RQ3. For teachers who do perform these types of tasks, what personal didactic praxeologies do they develop?

METHODOLOGY

In this section, we will now describe the methodology that was used for this research, from the collection of data to the coding.

Data collection – Questionnaire

We designed a questionnaire organised around the five types of tasks presented above and consisting of three parts. The first (A) deals with general information about the respondent. The second part of the questionnaire (B) consists of five questions in the same format, corresponding to the five types of tasks mentioned above, presented in the form of an objective (e.g. “I set up procedures and activities to achieve this objective: *Teach mathematical modelling*”). We would point out that the term ‘modelling’ could be understood differently by the participants. That justifies the following structure. For each, the respondents can answer on a Lickert’s scale how often: (1) always, (2) very often, (3) often, (4) sometimes, (5) never. If the answer is “never”, they are asked to specify a reason via a drop-down menu: (i) It's not my

responsibility, (ii) My students are not concerned by this problem, (iii) I do not have the time to do this in addition to the maths programme, (iv) I would like to do it, but I do not know how, (v) Other (open question). If the respondents did not answer "never", they were then asked in two following open questions to describe the way they do it ("How do you proceed to reach this aim?", technique) and then the reason for doing it this way ("Can you explain why you think this achieves this objective (why do you do it this way)?", technology). The last part (C) is optional and allows respondents to give comments and possibly volunteer for a future interview.

The authors have sent a link to the online questionnaire to colleagues in their universities, asking them to forward it to any teacher they know as mathematics teachers to non-specialists. The accompanying text of the questionnaire explained the aim of the research. We consider that the respondents were teachers interested by pedagogical and didactical issues linked with the teaching to non-specialist students.

Analysing the answers to section B

We collected 38 responses. In what follows, the respondents will be named R1, R2 ... R38. We firstly focused for each type of tasks on the "never" answers and the associated reasons. In a second step, we tried to identify for the other answers (from "always" to "sometimes") the personal techniques and technologies developed by the respondents. For each type of tasks, two researchers independently proposed a first coding, characterising the techniques (actions described by verbs with equivalent or similar meanings) and the technologies (justification of the choice of a technique). The two researchers confronted their coding, then these initial codes were discussed in the whole team and adjusted. We then followed a cycle of independent coding and confrontation until we reached agreement. In some cases, the answer to the question about the personal technology "why do you do it this way" was irrelevant: typically, the respondent said that the students need this, but without any explanation about the particular technique chosen. We classified such justifications as "no technology".

RESULTS

We first present some of the quantitative results from our questionnaire. Then, for each type of tasks, we analyse the responses of teachers who say they never try to achieve it. Finally, we present a qualitative analysis of two didactic praxeologies based on the verbatims obtained from the questionnaire responses. For the sake of brevity, we have kept here two types of tasks for this deeper praxeological analysis: 'Link mathematics and other subjects' (T_{lmo}) and 'Teach basic mathematics' (T_{bm}).

Global quantitative analysis of the answers

We asked teachers how often they implemented approaches and activities aimed at each of the five types of tasks (Figure 1).

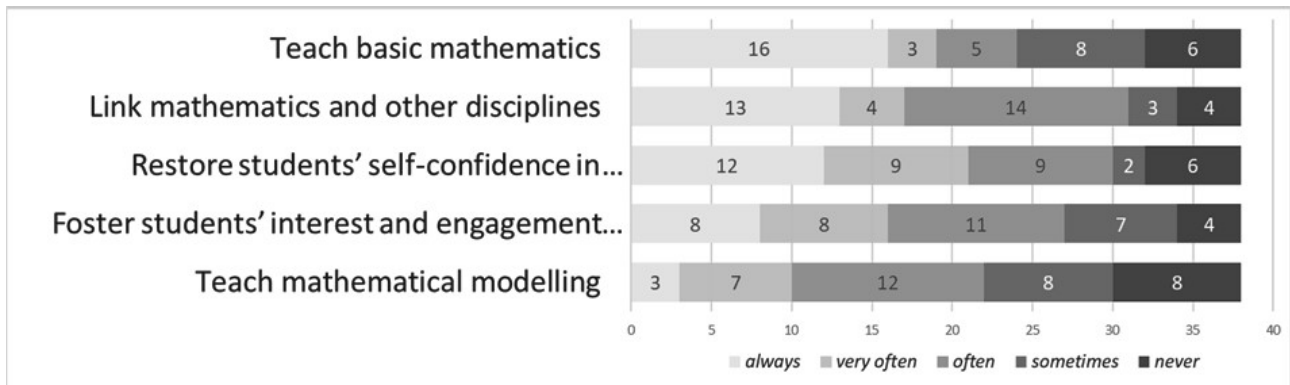


Figure 1: Occurrence of types of tasks in declared teaching practices

We would like to emphasise the large proportion of respondents who always “Teach basic mathematics” (T_{bm} , 16 respond., 42%), while only 8% of them always “Teach mathematical modelling” (T_{mm} , 3 respond.). Nevertheless, if we look more widely, 22 respondents (58%) answered always, very often or often for T_{mm} and 63% for T_{bm} : the difference is in fact minor. We also note the large number of teachers (31 respond., 82%) who “Link mathematics and other disciplines” always, very often or often. This can be a consequence of the concern of our respondents for teaching questions.

For respondents who address the different types of tasks, at least 84% explain how they do it, we considered it as an element of technique. Between 34% (“Teach basic mathematics”) and 78% (“Restore student’s self-confidence in mathematics”) of them explain why they do it this way (Table 1).

	T_{bm}	T_{lmo}	T_{scm}	T_{iem}	T_{mm}
addressing type of tasks	32	34	32	34	30
citing a technique	27	32	28	31	28
citing a technology	11	13	25	21	17

Table 1: Number of respondents tackling types of tasks and citing technique/technology

“I never do this!”: explanations

The type of tasks with the largest number of “never” choices is “Teach mathematical modelling (T_{mm})” with 8 selections. This is followed by “Restore student's self-confidence in mathematics (T_{scm})” and “Teach basic mathematics (T_{bm})” (6 responses). Finally, “Foster students' interest and engagement in mathematics (T_{iem})” and “Link mathematics and other disciplines (T_{lmo})” with 4 selections each. 14 of the 38 respondents selected “never” at least once. As for the reasons for “never”, “I do not have time to do this in addition to the maths programme” was the most frequently chosen option (13 times), followed by “My students are not concerned by this problem” (12 selections). For the record, respondents could choose several reasons. The third choice was “It's not my responsibility” (6 selections). None of the respondents chose the reason “I would like to do it, but I do not know how” (Table 2).

	T_{bm}	T_{lmo}	T_{scm}	T_{iem}	T_{mm}	Total	<i>Nb respond.</i>
(i) It's not my responsibility	1	1	0	0	4	6	5
(ii) My students aren't concerned by this problem	4	0	3	3	2	12	8
(iii) I do not have the time to do this in addition to the...	2	2	4	2	3	13	8
(iv) I would like to do it, but I do not know how	0	0	0	0	0	0	0
(v) Other	1	2	1	0	1	5	4

Table 2: Reasons given for never performing types of tasks

These responses raise several issues that point to the need for further investigation. We note the importance of the reference to insufficient time as a barrier. This may be related to the limited time devoted to mathematics, in the case of non-specialist students, compared to the curriculum to be covered. However, only 8 of the respondents mentioned this reason, so some teachers did not feel that there was a lack of time, and the reason could rather be the importance that they attach to this type of tasks. The reason "My students aren't concerned by this problem", also chosen by 8 teachers, may correspond to courses for selected high-achieving students. It may also mean that teachers have not (yet) identified a problem for their students.

“Teach basic maths” (T_{bm}): praxeologies

The most frequently used technique for T_{bm} is "Reminders during lessons" ($\tau_{bm_rem_inclass}$, 20 answers). This technique is sometimes mentioned without any further details on how these reminders are given. In some cases, the respondents provide more details:

- Presentation of contents: "With numerous and frequent reminders on the blackboard (left written during the session)" (R4) (16 answers)
- Reminders in the form of exercises: "I insert small exercises from previous classes" (R7) (9 answers).
- Re-explain or reconstruct: "I re-explain as much as possible based on basic concepts" (R2) (4 answers).

Teachers who use this technique provide few explanations as to why they do so. Only six teachers suggest a technology linked to $\tau_{bm_rem_inclass}$ (30% out of 20). Three teachers note that providing reminders during lessons helps reassure students concerning their mastery of the mathematical basics. Two of the four colleagues who declare that they re-explain or reconstruct content during these reminders present an elaborate technology. They explain the benefits for understanding of revisiting certain contents from previous years: "Students are often surprised to see that they actually know a

result if we present it differently, or that a reasoning is finally not so difficult if we take it from the basics" (R2).

Another technique, cited by seven respondents, is "Offering external resources or remediation outside the classroom" ($\tau_{\text{bm_outofclass}}$). This technique is compatible with the previous one: four colleagues provide reminders during lessons, and also offer support for students' personal work about secondary school content. The teachers using $\tau_{\text{bm_outofclass}}$ provide students with online resources (5 answers) and/or refer to specific support measures (3 answers): "There is also the assistance room¹ during the whole year, and a support project with personalised courses, for those who do not have the basic knowledge of high school" (R38). Three colleagues offer a technology associated with the choice of $\tau_{\text{bm_outofclass}}$: two say they do so because of a lack of time, and one considers that going back to basics is the student's personal task.

Five teachers use a technique we call "responding to requests and needs" ($\tau_{\text{bm_requests_needs}}$). These colleagues do not systematically present reminders to the whole class, but do so in response to questions or according to their perception of the students' needs. Concerning the technology, two of these colleagues mention the heterogeneity of the students, and the need to differentiate their reminders; two others say that they do it in order to "make elementary notions available" (R4).

We note that very few explanations of the technique seem to be linked with a reflection about the impact of teaching on students' learning. The respondents who declare that they propose resources out-of-class because time is lacking for reminders in class do not argue that they choose resources actually helpful for the students. The respondents presenting reminders in class do not provide details about these reminders; their relevance may depend on the teachers' knowledge of the secondary school curriculum, that is sometimes limited.

We note nevertheless that some teachers (5) teach basic mathematics according to the students' needs or requests. Pinto and Koichu (2022) in their international survey of teachers' views on the secondary-tertiary transition note that university teachers acknowledge the diversity of students and the need to take it into account in first-year courses; the technique $\tau_{\text{bm_requests_needs}}$ is directly linked with this diversity.

Most teachers replied without mentioning any specific mathematical content. However, six colleagues gave examples: literal arithmetic (1 ans.), fractions (2 ans.), percentages, proportions (1 ans.), triangle geometry (2 ans.). The topics mentioned are directly linked to the main disciplines studied by their students: percentages in economy-management, geometry in electrical engineering, for example.

"Link mathematics and other disciplines" (T_{lmo}): praxeologies

We identified four different techniques used (at least three times) to achieve "Link mathematics and other disciplines" (T_{lmo}). The disciplines mentioned by respondents are physics (5 ans.), economics and management (6 ans.), chemistry (3 ans.), biology and computer science (2 ans.) and finally medical study.

The most frequently used technique is "Proposing examples, exercises or applications linked to other disciplines" ($\tau_{lmo_exercises}$), (18 answers): "I propose problem situations in the fields of biology, genetics, chemistry, physics, etc." (R28). Nine of them did not give any explanation justifying this technique. For those who gave an explanation for this way of doing things, they explain that proposing this kind of exercise, in the context of another discipline, makes it possible to show the existence of links between mathematics and other disciplines (7 answers): "it makes it possible to link different areas of knowledge" (R34), "With this course, [we] make links between maths notations and physics notations" (R3). It seems to us that this kind of explanation cannot be qualified as a technological element, since it refers to the type of task and not to the technique. For these respondents, proposing exercises in the context of the other discipline creates a "natural" link that they struggle to justify.

Eight teachers used the technique of "Presenting mathematical concepts as a tool for solving a problem in another discipline" ($\tau_{lmo_math_as_tool}$), for example: "by introducing each mathematical concept as a tool for solving a physical problem" (R11). Regarding the technology, three of them explained that this technique makes it possible to support the students' ability to use mathematics in other disciplines: "a recurring problem is the students' inability to transfer the tools seen in maths to other disciplines" (R3); "The idea is not to replace the physics teachers but to have done a calculation "properly" once, in the maths course" (R9). One teacher justifies his way of doing by making links between this technique and future professional practices of these students: "The aim is to make applied engineers and not an expert in mathematics" (R15). Another teacher justifies this technique by saying that it leads students to manipulate mathematical concepts and formulae (R11).

Six of them explain implementing a program's course that is essentially multidisciplinary, responding to institutional constraints: "The program itself provides for certain links between maths and computer science (encryption, encoding of numbers)" (R13). According to us, their technique is part of the implementation of a multi-disciplinary program (institutional curriculum) ($\tau_{lmo_inst_curriculum}$), like R21 who explains: "In the BUT GEA [3-year post-baccalaureate course] national program, the content of the mathematics program is explicitly linked to a management course". Only two of them gave an explanation for using this technique, the aim being to show the existence of links between mathematics and other disciplines: "it's time to create a link between mathematics and agronomic issues" (R32).

Three respondents made the link with the previous didactic type of tasks "Teach mathematical modelling" (T_{mm}) and the questions they had already answered in the online questionnaire. They explain linking mathematics and other disciplines through modelling activities or situations: "same answers as before... this is what reinforces students' interest in mathematics, and it's linked to the modelling problem" (R1). The type of tasks "Teach mathematical modelling" thus becomes a technique ($\tau_{lmo_modelling}$) associated with the didactic type of tasks "Link mathematics and other disciplines" (T_{lmo}). These three teachers give no justification for using this technique.

CONCLUSION

To answer **RQ1**, a majority of the respondents tackle at least “often” each of the five didactic types of tasks in our list. The colleagues who answered our questionnaire are most probably concerned in teaching issues, we do not claim that this represents the practice of all mathematics teachers. The type of tasks “Teach mathematical modelling” (T_{mm}) has the highest proportion of 'never' or 'sometimes'. This is perhaps the most ambiguous type of tasks, since teachers can give different meanings to ‘modelling’. In fact, some answers refer to 'real modelling', which according to some respondents is too difficult to teach in the first year. Finally, as we pointed out in the previous section, T_{mm} can be used as a technique to address T_{lmo} .

Concerning the reasons for "never doing this" (**RQ2**), the reason "it's not my responsibility" was rarely given. The answer most frequently given was linked to a lack of time. The reason "my students are not concerned" requires further investigation to determine whether the students really are not concerned (e.g., the course only recruits high-achieving students) or whether the teacher has not diagnosed an existing need.

The didactic praxeologies developed by the teachers who tackle the five types of tasks are quite diverse (**RQ3**). At least 84% of them cite at least one technique. Far fewer cited a technology, especially for T_{bm} and T_{lmo} (less than 38%). It can be linked with a bias in our questionnaire: there were more technologies cited for the two first types of tasks, the respondent perhaps found the questionnaire too long. Nevertheless, it can also suggest that the teachers do not provide themselves with the means to ascertain whether the techniques they use actually make it possible to accomplish the types of tasks. However, some answers do contain some in-depth reflections, for example on how to deal with the heterogeneity of students.

With regard to the perspectives to this research, we would like to continue analysing the data collected, to see whether there is a link between the techniques declared and the teaching fields or initial training of teachers questioned. In our further work, we will firstly interview the teachers who gave their contact details, and observe their teaching. The observations in particular can shed light on the techniques they actually use and on the relevance of these techniques (for example proposing exercises in a kinematics context is not enough for making links between mathematics and mechanics (Hitier and González-Martín, 2022)). We intend subsequently to design a refined questionnaire, drawing of the analysis of the interviews and observations, and to submit it to a larger population, with the aim of carrying out a comparison between Argentina and France (which is not currently possible due to the small size of the sample). Our study could contribute to the training of university teachers by raising their awareness about these types of tasks, the different possible techniques and the need to question the reasons justifying a technique.

NOTES

1. The assistance room is a place open two hours each week where students can go to ask questions.

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